GAMIFICATION FOR BEHAVIOR CHANGE OF OCCUPANTS IN CAMPUS BUILDINGS TO AFFECT IMPROVED ENERGY EFFICIENCY

by

Jing Du, Yue Feng, Changchang Zhou

Dr. William Chameides, Advisor

April 2014

Master project submitted in partial fulfillment of the
Requirements for the Master of Environmental Management degree in
The Nicholas School of the Environment of
Duke University

Abstract

In 2012, 40% of total U.S. energy consumption was attributed to residential and commercial buildings. However, in order to improve building energy efficiency, most conservation measures adopted today are based on technologies or maintenance. In this project, we worked with Smart Green Institute to develop behavior-based energy saving measures, which are more cost effective and have fewer installation constraints. After selecting two campus buildings-Old Chemistry and Rubenstein Hall- for our case study, we analyzed the building utility and expense data from 2005 to 2013 to explore the consumption and expenditure trends, and figured out the relatively elastic and changeable energy sources to focus on. Then we conducted survey to occupants of the two buildings to study their consciousness of building energy conservation and awareness of gamification. Based on the study of building data and occupants' behavior, we proposed a tailored gamified energy conservation plan using the Behavioral Change Gamification Model.

Table of Contents

Introduction

Today, creating and maintaining highly energy efficient buildings have largely been based on the adoption of advanced technologies, such as installation of smart sensors and controls and efficient heating and cooling systems. Far less effort has been placed on trying to influence occupants' behavior to achieve energy savings. However, in many cases the latter one provides the least marginal cost. In new buildings technological fixes have already been applied. And it is often not realistic or economical to try to update or retrofit an existing building. Given all the above consideration, our project focuses on a new and emerging method for influencing the behavior of building occupants to improve building performance: game-based approaches or gamification. While there are many aspect of building performance that can be addresses through gamification, we focus here on energy efficiency. Heretofore, references to green building and/or building performance will denote building energy efficiency unless otherwise noted.

Using a case study approach, we focus on two buildings on Duke campus (Old Chemistry and Rubenstein Hall), both basic institutional buildings mainly containing offices and classrooms. We analyzed utility and cost data of the two buildings, conducted survey of building occupants to study their preference and behavior, and, on the basis of these findings, propose here a game-based plan for the two buildings to achieve better building performance.

This report is consisted of four chapters.

Chapter 1 presents a literature review of relevant research, including the state-of-the-science on green building technologies, human behavior that influences building performance and how to track and measure those human factors, as well as the practice of gamified integration and interfaces in real world.

Chapter 2 gives the methodology adopted to collect utility data for the two buildings selected here from the university, the data analysis process using Excel and results.

Chapter 3 illustrates the methodology used to conduct the occupant surveys, the data analysis process and a discussion of findings.

Chapter 4 serves as conclusion of the project, and provides specific game-based plan tailored for future building energy performance improvement in the two target buildings.

Appendix A is the occupant survey questionnaire.

Chapter 1: Background Research

1.1 Existing and Emerging Building Energy Efficiency Technologies

1.1.1 Basic Information of Green Building

According to the U.S Environmental Protection Agency, green building is defined as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction" (Green Building, EPA). Green buildings are intended to have a beneficial impact on their occupants and the surrounding environment throughout their lifetime and are known for their sustainability and high performance (i.e., efficient use of energy, water and other resources, protecting inside occupants health and improving the productivity, cutting down waste and pollution).

In 1993, the U.S. Green Building Council was founded to drive the revolution of green building construction. In March 2000, the U.S. Green Building Council developed LEED, or Leadership in Energy & Environmental Design. LEED 1.0, the pilot program was issued in 1998, including 14 LEED certified buildings. Ever since, LEED has gone through exponential growth world widely, given the number of the certified buildings – new and retrofit. (Ying Li, 2012).

LEED evaluation for sustainable buildings is the leading system for designing, constructing, and certifying green buildings, and the most widely used system in the United States as well. All over the world, more than 10,000 buildings across the architectural field from elementary schools and supermarkets even to the Empire State Building, have received a LEED designation. This number will continue to grow in the future. LEED has dramatically enhanced the way contemporary built environments are designed, constructed, and operated (U.S. Green Building Council).

LEED assess the following six performance areas:

• Sustainable Sites

• Water Efficiency

• Energy and Atmosphere

• Materials and Resources

• Indoor Environmental Quality

• Innovation and Design Process activities

The total construction credit could add up to 69 possible points that goes into one of four possible levels of certified status as follows:

– LEED Certified: 26 - 32

– Silver Level: 33 – 38

– Gold Level: 39 – 51

– Platinum Level: 52+ (69 possible)

1.1.2 Emerging Building Energy Efficiency Technologies

Initially in the 1980's and 1990's, green building designs usually focused on one issue at a time, such as improving energy efficiency, adopting passive solar design or using recycled and renewable materials. Since then green building architects began to adopt a more comprehensive approach that attempted to integrate all the factors that together constitute a "high performance" building (William E. Roper, 2007)

U.S. Climate Change Technology Program (2003) pointed out that based on current levels of building area products, there is huge potential to enhance the energy efficiency of the building sector. Presently, the efficiency of HVAC equipment, as well as lighting systems in the market vary from 20% to over 100% (geothermal heat pump could be as efficient than 100%). Additionally, only 40% of residences buildings are fine insulated, and commercial buildings with roof and walls insulation account for only 30%. Less than 40% and 17% of current windows are covered with low-E coatings in residential and commercial buildings, respectively. Reflective roof materials comprise less than 10% nationally (Marilyn A. Brown, 2006). We would expect substantial energy consumption reduction in the future with the application of the state-of-the-art green building technologies.

Appendix A discusses some of the most promising emerging building energy efficiency technologies in detail to provide a deep understanding of technologies trends in the future.

1.2 Study of Building Occupants' Behavior

While technology plays a major role in determining a building's performance, the occupants' behavior can also be important. For example if occupants use space heaters to warm their offices in the winter, they can frustrate attempts to conserve energy by controlling thermostats. Meanwhile occupants' behavior is complicated and unpredictable, and documenting its impact on building performance is significantly more difficult than tracking building data of energy consumption or water usage. In order to evaluate the impact of occupants' behavior on building performance, previous studies have paid most attention to two aspects: how to categorize and quantify human behavior and how to prove that human behavior can influence building performance.

1.2.1 Influence of Occupants Behavior on Building Energy Performance

Scientists started researching the relationship between energy-related human behavior and building performance from the 1980s (Raaij, 1983). Generally, the occupants can directly or indirectly influence a building's thermal level, air quality, noise level, lighting, humidity, etc. in some canses in obvious ways but in other cases in quite complicated and interactive manners. The purpose of studying human behavior in building science is basically two-folds: to design technology solutions independent of user behavior (Hose et al, 2009); to make full use of behavior-based solutions to achieve better building performance.

Numerous studies have established a link between human behavior and a building's performance. Table 1.1 provides a summary of some of the key studies on human behavior and building energy usage.

Table 1.1 Summary of Behavioral Studies in the Building Energy Sector

Year	Researcher	Methodology	Aspects of Behavior Studied	Results
1981	Fritzsche	Analyzed energy consumption pattern by family life cycle stage with ANOVA.	Stage of family life cycle. (Two classification methods)	The total household energy consumption demonstrated an inverted U shape as the life stage moved forward at the significance level of 0.01.
1983	Raaij	Proposed a theoretical model	Purchase-related behavior;	Advices on behavior modification as a short path

		to incorporate personal, environmental and behavioral factors into energy use analysis.	Usage-related behavior; Maintenance-related behavior.	action could be effective in energy conservation.
2006	Li et al	Studied a residential building in Beijing with a stochastic model to predict behavioral patterns.	AC operating times, temperature settings, and the habits of window opening and closing.	For different apartments in the same building, there are obvious differences in energy consumption patterns, which is caused behavior differences. These differences further led to differences in electricity use patterns from 0 to 14.3 kWh/m2 with average of 2.3 kWh/m2 in the same residential building.
2009	Ouyang et al	Adopted simulation tools to model certain behavior in buildings.	Operating times of electrical appliances (e.g: washing machines, bathroom heaters); Time at home; Age and average number of household members.	The average number of household members, their age, and the time they spent at home are the factors closely associated to energy usage in residential buildings. By informing building residents of energy conservation measures to improve behavior, more than 10% of household electricity use could be saved.
2009	Andersen et al	Adopted the means of multiple logistic regression model to study the survey data on behavioral control mechanisms.	Heating on/off, window open/closed, lighting on/off and solar shading in/ not in use.	It is statistically significant ($\alpha < 0.05$) that the four mechanisms are affected by ambient environment such as temperature and solar radiation.
2011	Korijenic et al	Adopted a single family building model to study the impact of occupants' lifestyle on energy usage with simulation techniques.	Heating demand in terms of temperature setting, time and area of heating.	The lifestyles of occupants have a significant influence on the energy consumption and GHG emissions of buildings. The energy consumption per unit area of Lifestyle 4 (658 kwh/m2) is more than twice of Lifestyle 1 (279 kwh/m2).
2012	Kubosumi et al	Carried out survey and interviews for tenants to	Movement of humans within the building;	Developed a web-based Building Energy &Interactive Communication System

		determine major barriers to energy efficiency and changeable behaviors.	Communication of tenants and building superintendents.	(BEICS) to track human movement with IP phone network to adjust air-conditioning temperature, and to allow tenants to vote for temperature settings.
2012	Hong et al	Adopted simulation techniques with EnergyPlus software package.	How occupants set comfort standards, operate lights, office equipment and thermostat	The simulation results demonstrated that the influence of occupant behavior on building energy consumption is significant. Compared to the standard/ reference work style, the wasteful work style consumes around 90% more energy, while the austerity work style consumes up to 50% less energy.

Despite the evidence showing the importance of human behavior in building performance, the design and certification of green building, for example through LEED, currently focuses on technological solutions rather than solutions based on shaping occupants' behavior. Therefore, it seems reasonable to assume that there is a great potential in further improving overall building performance by focusing on occupant behavior.

1.2.2 Methods to categorize and quantify occupants' behavior

Researchers have developed diversified ways and systems for categorizing occupants' behavior. For all proposed methods, the basic principle is to make human behavior quantifiable (i.e., so that it can be numerically described) and measurable. This allows for comparative studies of behavior data and building data (in terms of energy consumption, water usage, heating/ cooling demand, etc.).

Table 1.2 Summary of Methods to Categorize and Quantify Human Behaviors

Year	**Researchers**	**Methodology**
1983	Raaij	Distinguished among three energy related behaviors: purchased related behavior (the consideration of energy usage in purchasing durables), usage related behavior (day to day usage related to residents' habits) and maintenance related behavior (behaviors to maintain a in-home system).

2009	Hose et al	Categorized occupants' ways of influencing into two major categories: presence and activities.
2009	Andersen et al	Assigned binary variables to four specific behavioral patterns (Heating on/off, window open/closed, lighting on/off and solar shading in/ not in use), and calculate the possibility of the binary options.
2011	Korijenic et al	Developed four lifestyles to describe households' demand for heating: The heat demand increases by 190 kWh/m2, from 62 kWh/m2 in Lifestyle 1, to 252 kWh/m2 in Lifestyle 4.
2012	Hong et al	Categorized occupants' behavior into three work styles: 1) austerity: occupants are proactive in energy conservation, 2) standard: average occupants with moderate energy awareness, and 3) wasteful: occupants not concerned about energy use at all.
2012	Peng et al	Included three categories: time-related behavior such as window opening; environmental-related behavior in order to achieve a control objective such as temperature setting; random behaviors that are not quantifiable. Further developed three lifestyles of energy-conservative households, habit-adjusted households, and high standard households to study group behavior patterns.

1.2.3 Emerging simulation tools incorporating human behavior factors

In recent years, simulation techniques have begun to be adopted in building related studies on modeling building performance under different circumstances. Previous building simulation software packages tended to focused more on the effects of climate zones, building envelopes, mechanical systems and heating and cooling equipment, rather than the occupant's behavior. (ESRU 1999; Crawley et al, 2001; Klein et al, 2004; Yan et al, 2008; Zhang et al, 2008; EnergyPlus, 2009)

Faced with this situation, several models have been developed to incorporate the interaction of occupants and buildings. In 2007, Yun et al developed a time-dependent transition probability model and concluded that residents' window opening behavior patterns can be accounted for by three factors: room temperature, time of a day and the previous state of window. The probit analysis function is $P = \frac{e^{a+bt}}{1+e^{a+bt}}$, where t is defined as the indoor temperature, and a and b are constants in regression. At the same time, multiple probability sub-models are established for the start, intermittent and end of the occupation period to reflect the time of a day effects. The factor of window state is taken into account by indicating the previous and currents states in the model.

A comprehensive model developed recently by Bourgeois (2005) is the Sub-Hourly Occupancy Control (SHOCC) model that incorporates improved algorithm versions and copes with the usage of lighting, sun shading, window opening and indoor equipment to model occupants' behaviors. Results indicate that manual control of lighting and sun-shadings were able to achieve up to 50% reduction in the total energy consumption.

1.3 Behavior Modification Science

Behavior modification, also know as applied behavior analysis (ABA), refers to empirically derived techniques designed to influence the occurrence or frequency of certain behaviors. The research of behavior modification dates back to 1911, when E. Thorndike frequently mentioned "modifying behavior" in his article Provisional Laws of Acquired Behavior. Since 1940s and 1950s, J. Wolpe had adopted this term to describe psychotherapeutic techniques derived from empirical research.

1.3.1 Characteristics and methods of behavior modification

G. Martin and J. Pear (2007) concluded that there are seven characteristics of behavior modification:

- A strong emphasis on defining behavior in a measurable way
- Treatment techniques to alter the situation an individual is in
- Precisely described methods and rationales
- Frequently adopted in daily life
- Based on the Principle of Learning (i.e., both antecedents and consequences are able to change an individual's behavior)
- An emphasis that a particular technique is associated with a corresponding behavior change

- An emphasis on accountability for those involved in the practice of behavior modification

Common methods used in behavior modification include increasing the adaptive behavior through reinforcement, and decreasing the maladaptive behavior through techniques such as extinction, punishment or satiation, with an emphasis on reinforcement measures.

Reinforcement: Flora (2004) concluded that reinforcement could be regarded as the most important behavior change principle. It serves as a process of behavior strengthening, during with a stimulus leads to an increase of frequency of certain behaviors. Positive reinforcement refers to the addition of a stimulus (called "reinforcer") following a certain event, while negative reinforcement refers to the removal of a positive stimulus under similar circumstances (Cooper et al, 1987). Methods of positive reinforcement include compliments, approval, encouragement, and affirmation.

Extinction: Extinction is the process of discontinuing the reinforcement of a behavior that has previously been reinforced in order to lead to the reduction of that behavior (Miltenberger, 2008). For example, in Pavlov's experiment, after the dog was conditioned to salivate when hearing the bell ringing, it eventually stopped salivating to the bell after the bell had been sounded repeatedly without any food coming to it.

Punishment: Similar to reinforcement, punishment is a process during which a certain stimulus can be either added (in positive punishment) or removed (in negative punishment), while positive punishment is close to negative reinforcement mentioned above. Cooper et al (1987) summarized that there are in general three types of punishment: the addition of an aversive stimulus (such as pain), the removal of a desirable stimulus (such as fines), and the restriction of freedom (such as time-out punishment). And this is the most widely criticized method of behavior modification given the unwanted side effects associated with punishment such as emotional harm.

Satiation: Satiation effect occurs when someone's "appetite" (or desire) for a certain source of stimulation has been satisfied (Miltenberger, 2008). For example, for those who are not hungry, food cannot act as an effective reinforcer for behaviors. The inverse of satiation is more widely implemented in behavior modification practices in which a reinforcer tends to be more effective if an individual is deprived of it.

1.3.2 Effectiveness of Behavior Modification

Behavior modification has been proven to be effective in diversified fields aimed at specific issues such as developmental disabilities, mental illness and education, etc. A representative list of studies that have showed the effectiveness of behavior modification in different fields is shown in Table 1.3 below (Miltenberger, 2008).

Table 1.3 Summary of Behavior Modification Applications

Year	Researcher	Aspects of Behavior Studied	Results
1983	Repp	Developmental Disabilities	Behavior modification methods can be used to teach people with developmental disabilities various functional skills to overcome certain deficits.
2000	Dixon & Holcomb	Mental Illness	Behavior modification is adopted to treat patients with chronic mental illness to modify their behaviors such as living skills, social behavior, treatment compliance, aggressive behavior and work skills.
2008	Bambara & Kern	Education and Special Education	In order to reduce problem behaviors in the classroom, researchers analyzed student-teacher interaction and improved teaching methods with behavior modification techniques.
1994	Bakke	Rehabilitation	In order to teach skills lost through injury or trauma, behavior modification is used in rehabilitation to promote compliance.
1985	Hersen & Bellack	Clinical Psychology	In clinical psychology, behavior therapy has been used to treat a wide range of mental problems.
2010	Bailey & Burch	Business, Industry, and Human Services	Organizational behavior modification used in business can result in increasing productivity, profits and job satisfaction.
2009	Beck & Miltenberger	Prevention	Behavior modification methods have been applied to preventing problems in childhood such as sex abuse or child abduction.
2009	Boyer	Sports Performance	Behavior modification science has been used to improve athletic performance in various sports.

1.3.3 From Behavior Modification to Gamification

Recently, the idea of behavior modification, especially punishment, has been criticized widely, given the unwanted side effects (Miltenberger, 2008). For instance, punishment in practice may lead to emotional disorder, or reinforced activities on avoiding punishment ("not-being-caught"). Even with positive reinforcement, sometime resentment can arise along with the feeling of being manipulated. In addition, some researchers have criticized that implementing behavior modification procedures requires certain level of training, which is time consuming and not practical in some real life settings. To avoid such negative effects some behaviorists have proposed using "gamification" as an alternate path to behavior modification (Petkov et al. 2011).

In contract to behavior modification that imposes or removes stimuli to affect a behavioral change, gamification attempts to achieve the same result by creating an entertaining and engaging experience using the elements of a game or contest. (Petkov et al, 2011). According to Blohm (2013), gamification has four major elements that significantly increase its acceptance: increase of user satisfaction, conveyance of optimism, facilitation of social interaction and provision of meaning. In this way, compared to traditional behavior modification methods (such as punishment), gamification relates behavioral or habit change to positive emotional feedback.

1.4 Practice of game data integration and interfaces in real world

Currently, gamification is being used in several industries to improve production effectiveness, boost team cohesiveness, and educate employers. Gamification usually includes game elements such as leaderboard, rankings and points system, to create entertaining and engaging experiences. Furthermore, computer-based games and board games targeted at tackling climate change issues for example, have also increased significantly over the last decade (Reckien and Eisenack, 2013). However, games that are directly related to campus building (non-dormitory) efficiency improvement and building management are nonexistent. We examined several articles relating to game design and utilize them as guidelines for our recommended behavior changing game in Chapter 4.

1.4.1 Game, Perception, and Participation

Gamification, in most circumstances, is used as an innovative management tool for many industries. We believe that it can be considered as a new "technology" which strives to create entertaining experiences while accomplishing serious personal, social, or business goals. Therefore, Technology Acceptance Model developed by Davis (1986) is used to analyze and understand important elements that could lead to a successful gamification design. Based on the model, acceptance of new technology correlates with perceived ease of use and perceived usefulness. They are two important factors in determining whether people are willing to accept a new technology, or being specific in this report, gamification. Perceived usefulness seems to have a linear relationship with participation, meaning that people are prone to accept gamification as the perceived usefulness becomes stronger. However, the effects of perceived ease of gamification is comparably hard to determine, because intriguing games should be challenging and at the same time manageable by players.

Thus, game design is the most important element in gamfication. Games with simple tasks may bore participants, but games with tasks that are too complex or impossible may cause participants to quit. Csikszentmihalyi (1997) developed the Flow State Model, describing the psychological outcomes when individuals face challenges that are appropriate to their skills. In his book, the best psychological outcome of engaging an activity results from interaction between challenges and skills and is named as "Flow State ", or "Optimal Experience", a mental state of total involvement with great focus and enjoyment. Csikszentmihalyi (2009) argues that two conditions are required to experience the flow state:

1. Perceived Challenges: Challenges that stimulates participants' full utilization of their skills, while making participants believe that goal achievement matches their skill level.
2. Clear Goals: Goals that can help divide the overarching goal into manageable tasks and provide immediate and clear feedback to participants.

Abilities might be enhanced during games, but they are developed gradually. Breaking goals into manageable pieces could help participants reach "Flow" state in each activity and eventually achieve the overall goal with great self-fulfillment. For example, a class is taught by assigning homework and readings first, and then the instructor could use an exam to help students focus on what is important and thus achieve learning objectives. Adversely, if the instructor distributes the exam without providing any related knowledge and asks students to complete the exam in class, students could experience anxiety and might even quit studying. Therefore, appropriate task assignment at each stage is critical in helping participants achieve goals and encouraging engagement.

Figure 1.1 summarizes the Flow State Model. If challenges are tough while abilities are low, participants may feel worried and anxious. However, when required abilities are high and challenges are low, participants can experience boredom and relaxation. In a low challenges and low abilities situation, people tend to avoid participation because they feel apathy to the tasks. Thus, the state of flow only when challenges and abilities are commensurate. A series of games that continually raise expectations can lead to an ever-increasing skill level on the part of the

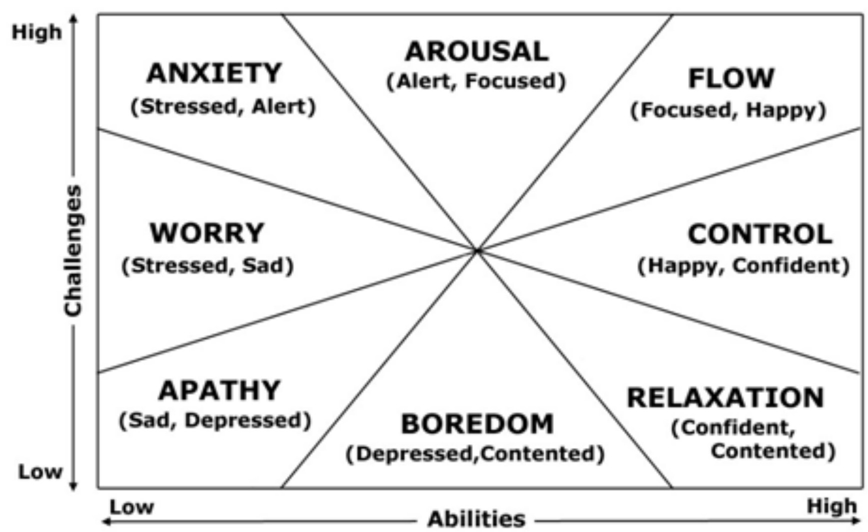


Figure 1.1 – from PositivPsykologi

Source : http://www.positiv-psykologi.se/wordpress/lycka/

participant.

Another important factor is that human perception can be biased by personal knowledge and previous experience. For example, an environmentalist might see energy efficiency as a good because of its impact on the environment; a small restaurant owner might be attracted by the saving of money. Recognizing these differences and developing linkages between individual priorities and the overarching goal of the gamification is critical.

1.4.2 Game and Knowledge Management

One of the purposes of gamification is to motivate behavior change, especially in the context of this report. Reluctant to or lack the awareness of changing current behaviors usually relates to the absence of understanding the deficiencies of these behaviors and benefits of new behaviors. Therefore, gamification can be used to address these issues via education by entertaining means. Thus, understanding the process of knowledge management is the foundation of developing successful games to “provide education to deal with real-life issues” (Reckien and Eisenack, 2013), also known as “serious games”.

Nonaka and Takeuchi (1995) developed the SECI process model to describe how knowledge is distributed from a group to individuals. They first divide knowledge into two dimensions, explicit knowledge and tacit knowledge. Explicit knowledge is usually in formal and systematic language, including words, numbers, and graphs. Knowledge in this format can be transmitted among individuals quickly and easily. On the other hand, the tacit knowledge is personal and subjective, and it is primarily based on individual understanding and practical experience. In Nonaka and Takeuchi’s SECI process, knowledge circulates in a loop model (Figure 1) transforming from tacit to explicit dimension, and then tacit again.

The SECI process model includes four stages: socialization, externalization, combination, and internalization. The first stage of the loop model is socialization in which knowledge is developed and shared through observation, conversation, and imitation, and thus it helps transmit tacit knowledge among individuals. The second step, externalization, is to transform tacit knowledge into the explicit dimension in the forms of documents or procedures. Further, this explicit knowledge needs systematic improvement in order to transmit knowledge to different social groups easily. Therefore, the third stage, combination, is to sort, combine, and categorize previously developed explicit knowledge so that they can be easily spread in different organizations. Finally, individuals learn knowledge through "learning by doing"[2], and transform explicit knowledge back to the tacit dimension. Thus, the loop model keeps circulating and helps develop knowledge among individuals and organization infinitely.

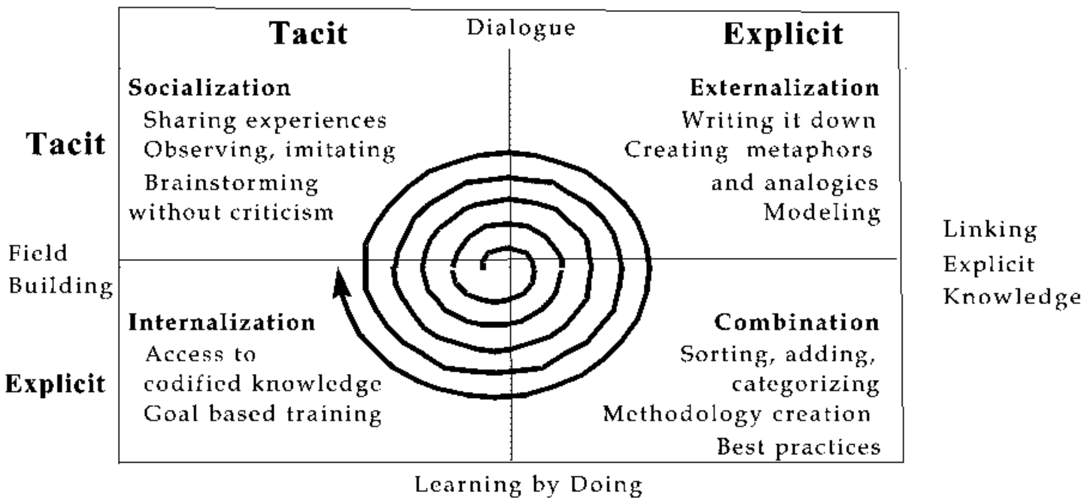


Figure 1.2 – from KM application

Source: http://inaz.edublogs.org/week-4-tacit-and-explicit-knowledge-knowledge-transfer-system-seci-model/

1.4.3 Gamification and Changing Behavior

Game design concepts that focus on changing behavior have been developed in recent years. Though its effectiveness remains controversial, some successful examples do exist. For example, the retailer Target has introduced a gamification strategy to increase checkout efficiency and evidence suggests the strategy has resulted in lowered checkout time as well as higher employee morale (Kiss Metircs and Enterprise Gamification Consultancy). Moreover, City of Hollywood, Florida, successfully increased the recycling by 130% within one year by partnering with RecycleBank, company that focuses on encouraging recycling by distributing coupons of major brand to participants (Hollywood official website). The design of these types of games closely ties to knowledge management and human psychology as presented in above sections. Velicer et al (1998) developed a five-stage model of the behavior change lifecycle which contains 1) recognizing the opportunity for improvement; 2) committing to the change effort; 3) learning how; 4) initial adoption of target behaviors; and 5) mastering and maintaining the target behaviors. They argue that each stage contains a challenge, and an individual must overcome the challenge in order to proceed in the model and finally complete the behavior change. Accenture Technology Labs utilizes this model to analyze existing behavior changing games that help overcome challenges in each stage.

The challenges for the first three stages often involve helping participants understand their current behaviors before making changes. In the first stage of recognizing improvement opportunities, the challenge is to help participants identify and realize deficiencies in their

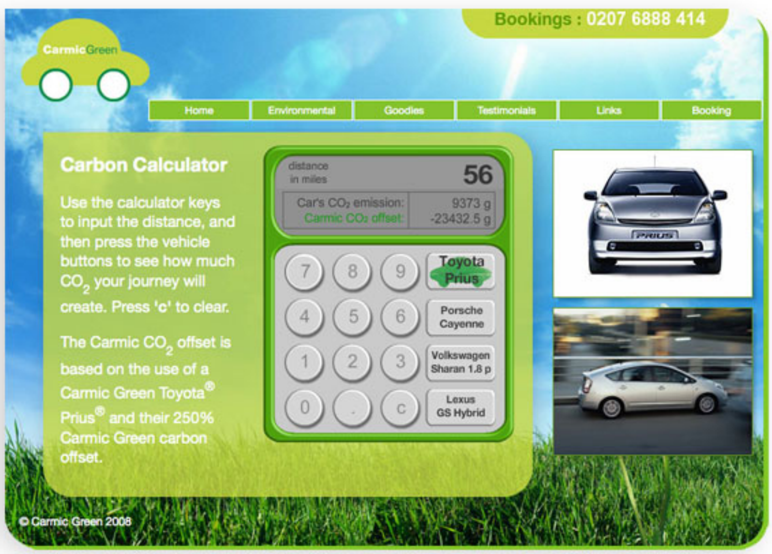


Figure 1.3 Carbon Calculator – from Green Bride HOE Guide

Source: http://www.greenbrideguide.com/content/what-carbon-offsetting-and-why-does-it-matter-your-wedding current behaviors and the possibility for improvement. Games like carbon calculator could fulfill this purpose by informing users of their current carbon footprint. It allows the user to understand the emissions of her current lifestyle and to learn opportunities to make significant performace changes through changing life habits.

Second, assisting players to commit to the change effort involves helping them envision the benefits of changed behaviors. Individuals sometimes might not be aware of the impacts of their current actions and they might be skeptical about changing these behaviors. Games help players establish a favorable cost/benefit ratio of changing behaviors that could have a positive influence on establishing change commitment. Cold Stone ice cream company uses game named Stone City, which contains interesting narratives, to educate new employees the long-term

Figure 1.4 Stone City – from Gamasutra

Source:http://www.gamasutra.com/view/feature/1543/persuasive_games_how_i_stopped_.php?print=1

consequences of incorrectly making ice cream. The game breaks the grand mission (correct ice cream portioning) into various manageable missions. It helps new employees foresee the impacts of wrong behaviors and communicates that it is worth changing their behavior since the effort is manageable.

Then, as players realize and understand their standard behaviors, educating them about the mechanisms of the target behaviors and how to make changes is important. SimCity and other simulation games serve this purpose by placing the player in the manager position to inform them about key factors for successful behavior change.

Figure 1.5 SimCity – from Positech Games

Source: http://positech.co.uk/cliffsblog/2012/12/31/sim-city-4-rekindles-my-inner-stats-geek/

Finally, providing active feedback and stimulating social interaction with other players are great means to address the last two stages. The initial adoption of target behaviors should be encouraged by providing sufficient positive feedback such as scores, prizes, or advancement within the game. Also, creating a safe environment for players is important, especially for players who are worried about the cost of changing current behaviors. As players participate more actively due to the positive feedback they receive, having them compete with other players could help reinforce and maintain the target behavior. Therefore the goal for the last stage, mastering and maintaining target behaviors, can be achieved. Within these games, players should know they can reach the next level but must be challenged in the process.

A Boston-based efficiency startup, MyEnergy, incorporates gamification theory into energy management, and their strategy could be an appropriate example to address challenges in stage 4 and 5. The company works with utility companies to develop a free reward online program to allow customers to compare monthly utility usage with neighbors. The online program records usage data and provides points for each kilowatt hour of energy, 10 cubic feet of natural gas, or 100 gallons of water saved each month. Customers can use rewarded points to purchase commodities, for example potato chips, from MyEnergy's partners. Moreover, MyEnergy also launched a program in Minnesota to encourage custumers to form teams and compet for prizes. A team up to 25 people can win over $7,000 or more. MyEnergy'sgamification system helped a community in Illinois save 14 percent of energy during heating and cooling seasons (GreenTech Advocates).

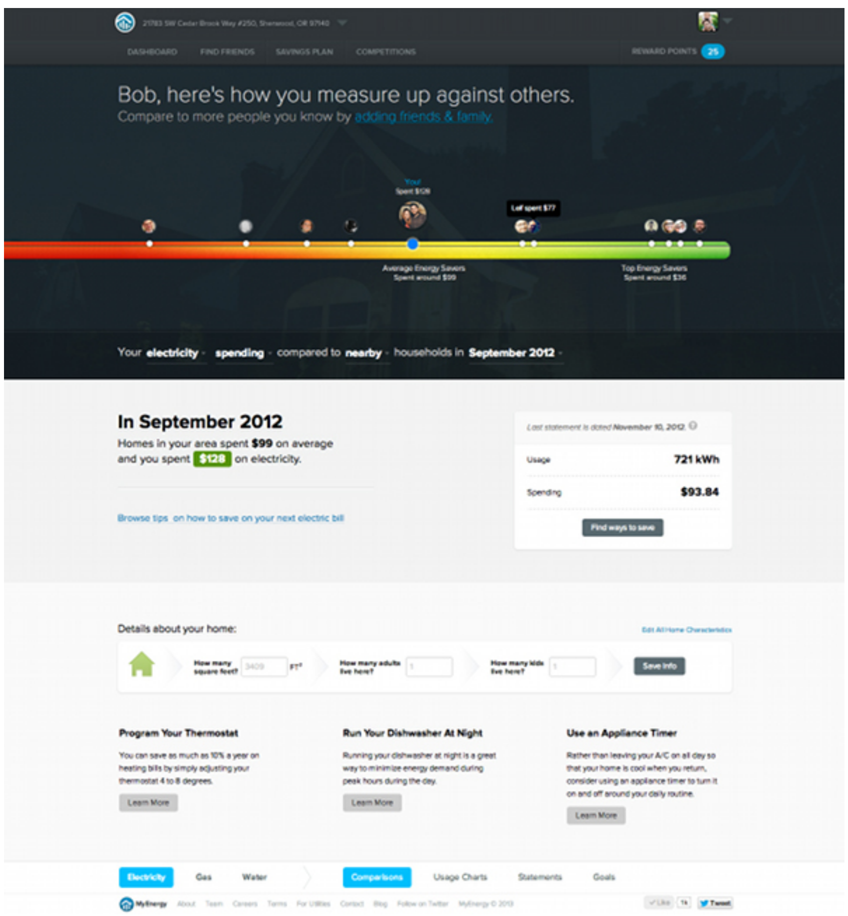


Figure 1.6 Personal Account Page in MyEnergy – fromVentureFizz

Source: http://venturefizz.com/blog/myenergy-helps-consumers-track-energy-savings

1.4.4 Summary

Effective gamification should address issues in human psychology and knowledge management, and achieve the state of flow. Since people tend to practice old behaviors due to the lack of knowledge in realizing the disadvantages of those behaviors and ways to change, gamification should first serve an educational tool to help participants realize the disadvantages of current behavior and provide advices on how to change behavior. As these messages are learned by the participants, gamification could then be used to stimulate real actions and to encourage continuing practice of the new behavior, and thus actually changing behavior.

In order to recommend a successful behavior-change-gamification event, we combined the five-stage model with the knowledge management model, and created a new model Behavior Change Game Model. This new model is the framework for our game recommendation, discussed in detail in Chapter 5. The Behavior Change Game model is primarily based on the circulating process of the knowledge management model. We assign a challenge in each of five-stages of the model corresponding to each of the four knowledge management states (i.e. socialization, externalization, combination, and internalization). Similar to the knowledge management model, the entire process starts with a Socialization Game in which participant discussion is used to increase appreciation of the benefits of changing behaviors, thus allowing the participants to recognize the opportunity for improvement (stage 1).

As potential participants start to realize the opportunity for improvement, the process could move forward to an Externalization Game. During the Externalization Game, games similar to Carbon Calculator and Stone City could be used to either help participants reinforce the idea of behavior improvement (stage 1) or help them address the challenge in committing to the change effort (stage 2). During the process, game facilitator needs to decide ways to help participants transfer from stage 1 to stage 2 based on their performance. If participants display signs of having difficulty to realize the improvement, facilitator might consider using games to address this problem. Further, if participants seem well prepared to advance to stage 2 challenge, facilitator might need to switch games.

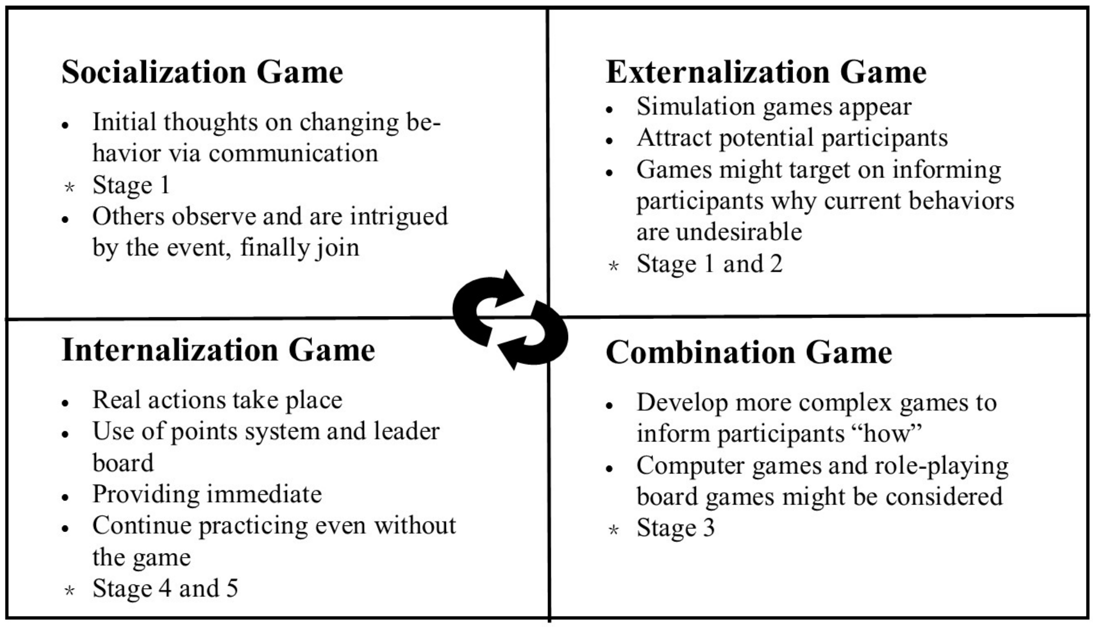
The completion of the first two stages could lead to a Combination Game in which participants could learn how to make changes. Games in this process should help players develop linkages between awareness and taking real actions by providing guidelines of how to adapt to new behavior, or learning how (stage 3). This is a critical step because specific suggestions of the new behavior first emerge. Games designed for this purpose should guide participates realizing that adapting new behaviors is easy to conduct, thus increase the likelihood of taking real actions.

Further, participants could advance to Internalization Game in which real actions occur. Initial adoption of target behaviors (stage 4), and mastering and maintaining the target behaviors (stage 5) are the objectives in Internalization Game. In order to encourage actions taking place, facilitators could use a points system and/or leader-board to develop competitions. Rewards can be distributed to winners for encouraging engagement.

Finally, as the gamification event becomes successful, it will attract more participants and the loop will continue to circulate.

However, this Behavior Change Game Model is developed for almost all behavior changes which can be realized through gamification. Therefore, some components in the circulating process are adjustable based on different scenarios. For the purpose of this report, Combination Game, which intends to educate participants how to make changes, might be unnecessary, since the targeted behaviors involve only simple actions such as turning off switch and adjusting for thermostat.

Figure 1.7 Behavior Change Game Model



Stage 1 - recognizing the opportunity for improvement; Stage 2 - committing to the change effort; Stage 3 - learning how; Stage 4 - initial adoption of target behaviors; Stage 5 - mastering and maintain target behvaiors

* - stage needs to be addressed

In conclusion, a single game might be insufficient when considering how to foster behavior change. Participants in different stages might need various games to address the associated challenges. In order to attract participants and develop successful games, surveys and interviews to gather information about potential players and their values and concerns can be crucial.

Chapter 2: Building Data Analysis

In this chapter, we selected two buildings on Duke campus- Old Chemistry and Rubenstein Hall- for our case study. Since the energy/ water consumption of laboratory or hospital facilities are relatively inelastic, these two buildings are selected since they consist of mostly teaching and administrative facilities with few or no laboratories. However, in terms of construction time, Old Chem is one of the oldest buildings on Duke main Campus, while Rubenstein Hall is newly constructed in 2000s with LEED certification. We specifically studied their specific energy/ water consumption pattern and expenditures in this chapter.

2.1 Background of Target Buildings and Energy Resources

The locations of the two buildings on Duke campus can been seen in Figure 2.1 and the details of the building characteristics are presented below. And some basic information of the two buildings is summarized in Table 2.1.

Figure 2.1 Locations of Old Chemistry and Rubenstein Hall on Duke Campus

Building Name	Construction Year	Square Feet	LEED Certified
Old Chemistry	1932	72,732	No
Rubenstein Hall	2005	66,446	Yes

2.1.1 Old Chemistry

The Old Chemistry Building (72,732 square feet) was originally constructed in the year 1932. It mainly consists of classrooms, offices plus a few laboratories. Departments of German, Statistics and Earth and Ocean Sciences are located in this building. Given the age of Old Chemistry, it is not surprising that it was built with minimal concerns about sustainability, and, given its design, it would be extremely expensive to add significant technological retrofits. The most recent major renovation of Old Chem took place in the year 1991.

2.1.2 Rubenstein Hall

In order to provide space for the expanding public policy program of Sanford School, Rubenstein Hall (66,446 square feet) was constructed in the year 2004 and opened in 2005, housing the Center for Child and Family Policy and the Duke Center for International Development. Rubenstein Hall is a LEED certified building. The location of Rubenstein Hall satisfies the requirements of a sustainable site with easy access to public transportation, minimum use of dark asphalt and appropriate landscaping to reduce irrigation needs. Through low-flush toilets and special fixtures, Rubenstein achieved a 30% reduction in water consumption comparing to the baseline level of similar size buildings. And it also achieved more than 15% of energy conservation by installing occupancy sensors and efficient lighting. The construction materials used are mainly Low-VOC paints, carpeting, sealants, adhesives and wood composites, which has met the LEED's requirements on materials and resources. In addition, Rubenstein allows natural daylight to reach 75% of the building's interior, reducing the demand for lighting in the daytime and creating a more productive work environment for its occupants.

2.1.3 Energy Sources

For almost all buildings on Duke campus, the energy demand is satisfied with three major sources: steam, chilled water and electricity. Duke University has adopted a district heating and cooling system with on-campus central plants; in this way buildings are heated with steam and cooled with chilled water. High-pressure steam is generated at two campus plants and distributed to each building as the main heat source. The chilled water system provides chilled water to satisfy the demand for equipment cooling and air conditioning in an efficient and economical mode. Electricity is purchased for electric utility company (Duke Energy, the largest electricity holding company in the US supplying approximately 7.2 million customers) to provide power for campus buildings, and is distributed at high voltage (15,000 Volts) within the bounds of campus to minimize transmission losses.

As for water usage, Duke campus is connected to Durham's municipal water system, with approximately 34 miles of city water and sewer lines. In addition, Duke has built a storm drainage system to collect storm water runoff, and has been installing a on-stream pond to further increase its storm water reclamation capabilities and reduce portable water consumption on campus. Most storm water will serve as the primary source for the all-year operating chilled water system.

In terms of thermal comfort control, Duke University has adopted a unique system named "Temperature Scheduling". Each building on campus can choose to opt in this system or keep its original way of temperature control. For buildings participating in temperature scheduling (such as Rubenstein Hall), the department of facility management will remotely control the building temperature setting on a seasonal basis, while the building occupants have no control. For building not participating (such as Old Chem), a separate thermostat is installed in each room of the building, allowing the occupants to set the room temperature on their own.

2.1.4 Data Source

Our data for utility usage and cost were accessed from the EnergyWitness online database of Duke University Facility Management Department (FMD). Utility data obtained through FMD depicts the monthly and annual energy consumption and cost in Old Chem and Rubenstein, and were categorized into chilled water, steam, electricity, storm water and water sewer. The data reveal variations that reflect the beginning and ending time of academic terms, summer and winter vacations.

Peaks and valleys in the graph lines are likely to be associated with the university academic calendar and seasonal changes. For reference, at Duke university the winter term begins in early January, a ten-day spring break is scheduled in mid-March, the spring term ends in mid-May, the fall term begins at the end of August, and the winter break begins in mid-December.

2.2 Analysis of Energy/Water Consumption

2.2.1 Consumption over time

The consumption of three major energy sources from July 2007 to Jan 2014 is plotted as below.

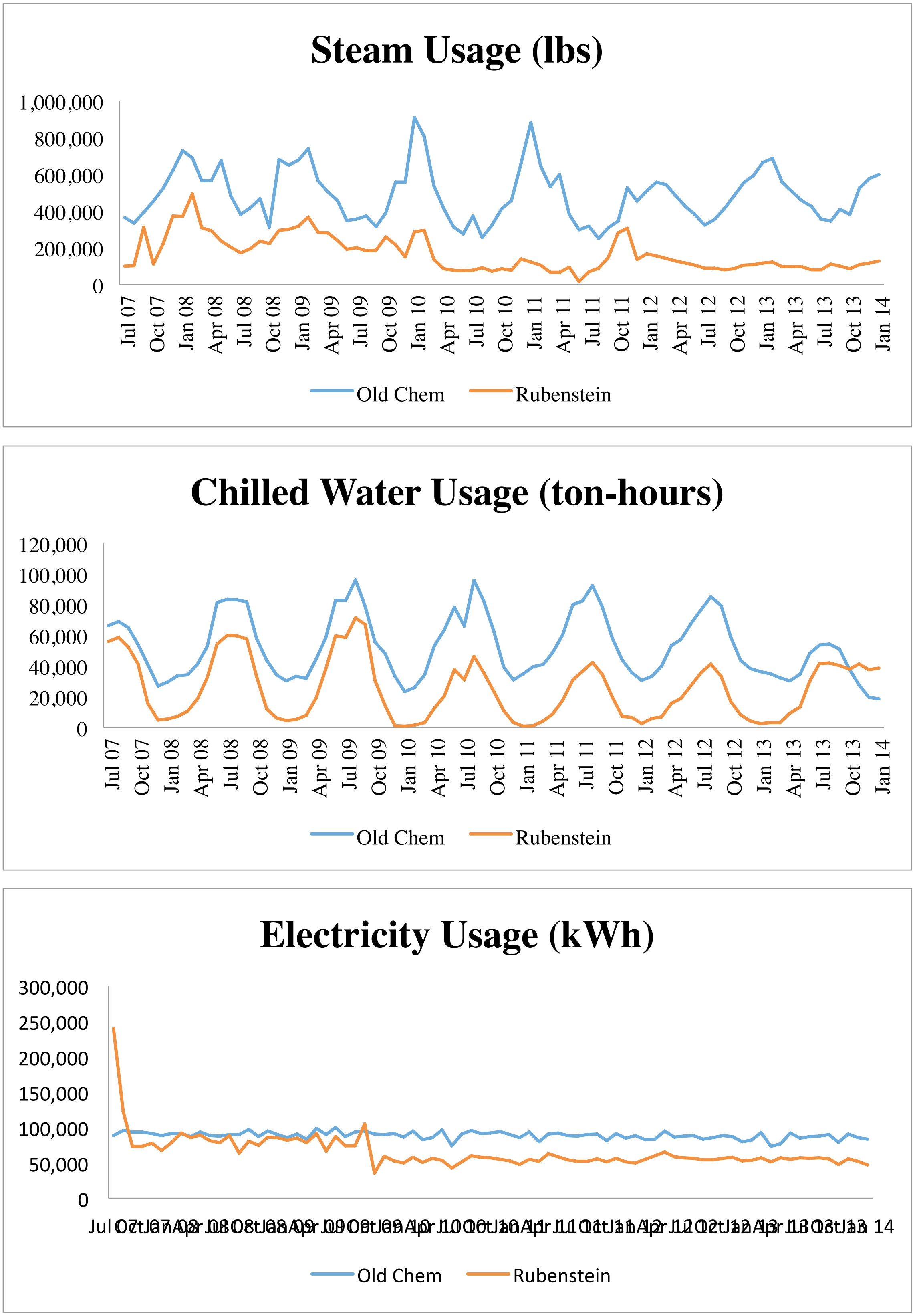


Figure 2.1 Usage of Steam, Chilled Water and Electricity from FY 2007 to FY 2013

Although Old Chem and Rubenstein differ slightly in consumption peaks or patterns, the energy consumption follows a similar seasonal pattern as shown above.

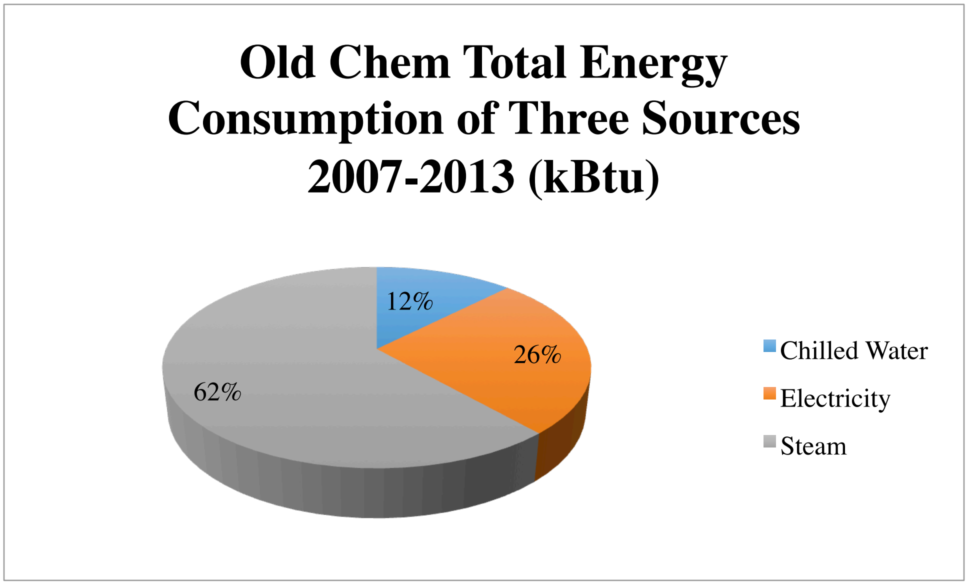
Steam: Since steam is used for heating purposes, for both of the buildings, the steam consumption peaked in January to February and reached the lowest point in summer. This peak and valley pattern is more significant for Old Chem data, since the energy demand of an older building (such as Old Chem) to maintain a set temperature is greater than newer ones. Due to differences in building envelope and HVAC system, the influences of outside temperature on these buildings differ. It is worth noted that although the steam consumption reached its peak at the same time every year, the level of the peak differs. One possible reason is temperature differences in these three winters.

Chilled water: Since chilled water is mainly used for cooling purposes, its consumption gradually increased in the spring, peaked at June to August, decreased in the autumn and reached the lowest point in every winter. The chilled water consumption of Old Chem is higher than that of Rubenstein, which is probably because Old Chem is larger in size, older in construction time and contains a few labs with higher cooling requirements.

Electricity: Since heating and cooling demands (which vary most along with the season) are mostly satisfied by steam and chilled water, the consumption of electricity is relatively stable for both of the buildings throughout the year, except for a sudden increase in Rubenstein in October 2011.

According to the Facility Management Department, the water data of Old Chem is not reliable since the old metering system cannot separately record each building's water usage on Duke main quad where most buildings were constructed in 1930s. So our study would not take water into account, but focus on energy sources.

2.2.2 Comparison of Energy Sources



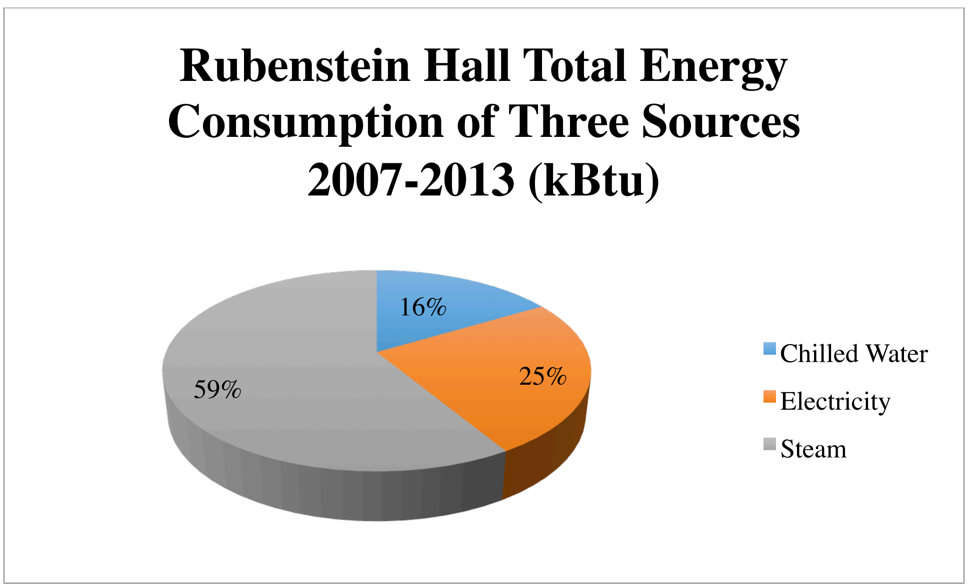


Figure 2.3 Total Energy Consumption of Three Sources for Old Chem and Rubenstein

In order to compare the energy consumption of different sources, we convert their units uniformly into thermal unit- kBtu. Figure 2.3 demonstrates that for both of the two buildings, steam is the largest energy source that accounts for about 60%, followed by electricity and chilled water.

2.2.3 Unit consumption

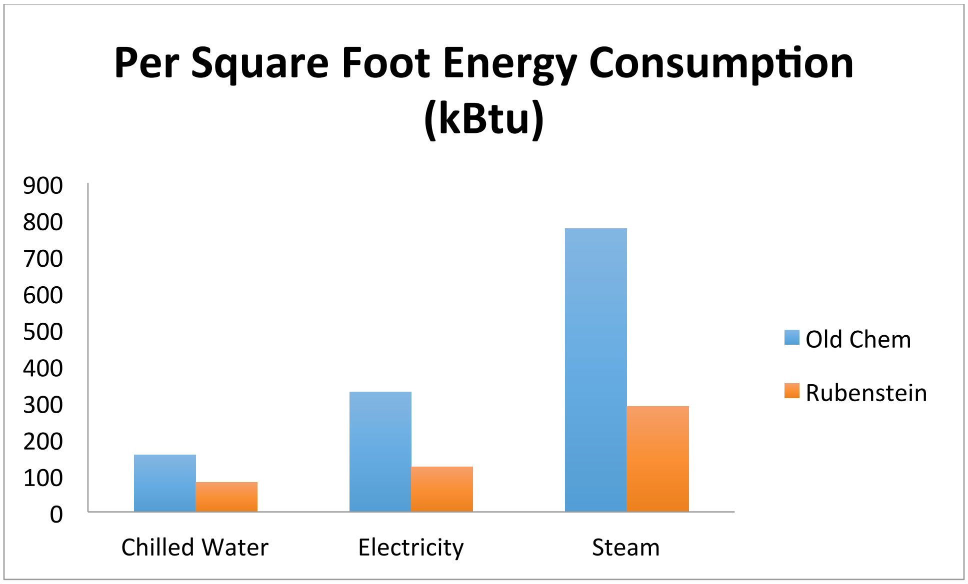


Figure 2.4 Per Square Foot Energy Consumption

According to Figure 2.4, when we divide the total energy consumption by the total square feet of the two buildings, it is clear that for all three sources, Old Chem consumes more energy than Rubenstein Hall per square foot. The reason is probably two fold: Old Chem was built about 70 years earlier than Rubenstein Hall, whose energy efficiency is inevitably inferior to a building constructed after 2000; Old Chem hosts a few laboratories which may lead to higher energy use compared to a building with only teaching and administrative facilities.

2.2.4 Elasticity

As noted above, the manager of all campus buildings can choose to opt in or out of the temperature scheduling system. Rubenstein Hall, as a participant in the system, has relatively inelastic steam and chilled water consumption. However, for Old Chem, the steam and chilled water consumption are rather elastic since its occupants controll the building's heating and cooling.

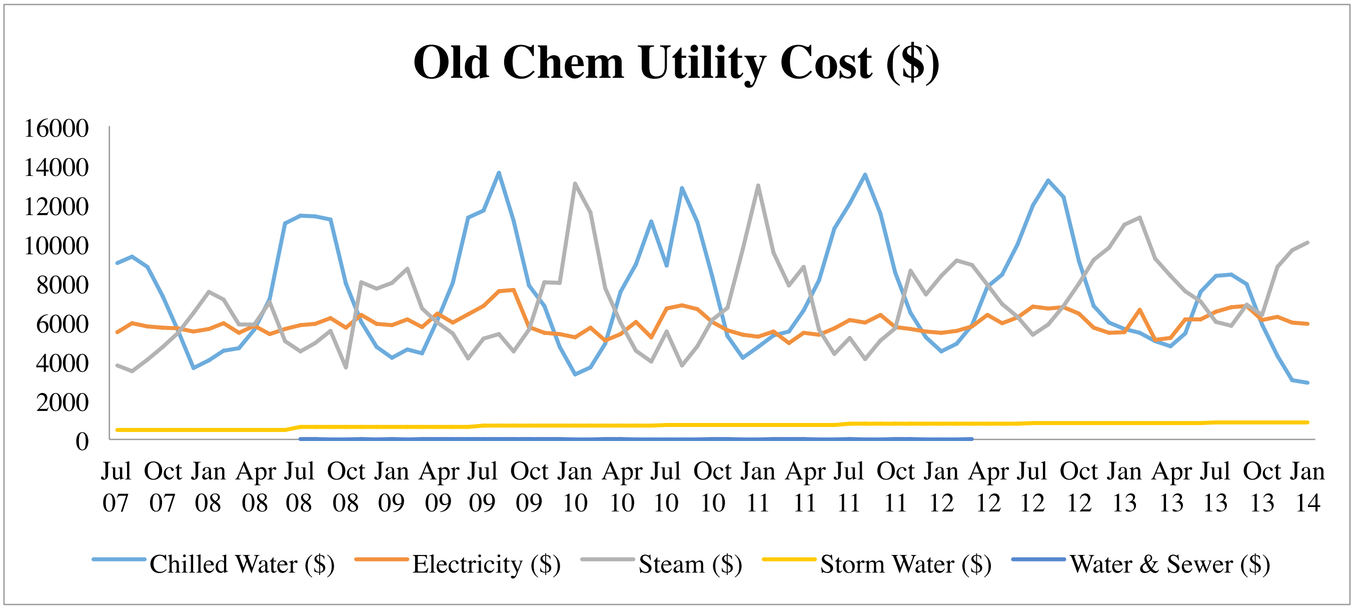
By contrast, electricity and water usage are subject to occupant behavioral influence in both buildings. (But: the water data are not reliable.)_

2.2.5 Analysis of Electricity Consumption

According to EIA data, in the year 2009, the end user electricity consumption in the United States consisted of 41.4% of space heating, 34.6% of lighting and appliances, 17.7% of water heating and 6.2% of air condition. Given the adoption of steam and chilled water on Duke campus, we can infer that the majority of electricity consumption for the two target buildings comes from lighting and electrical appliances.

2.3 Analysis of Building Expenditure

2.3.1 Trend over time



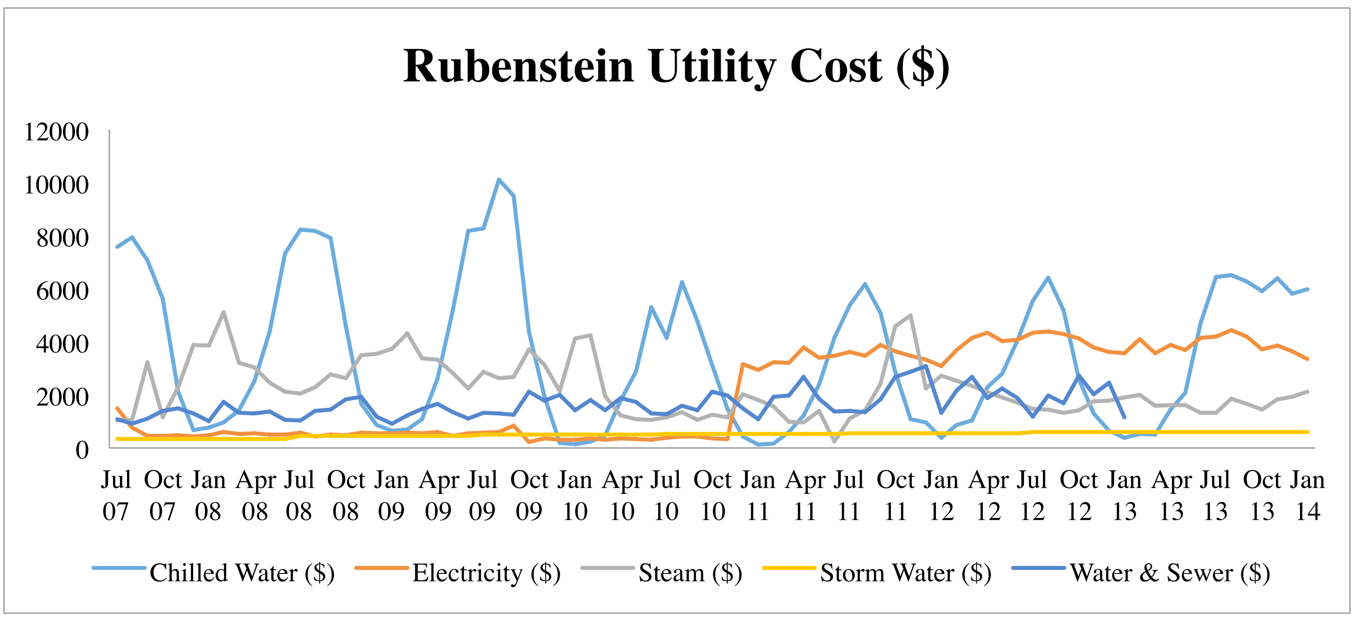
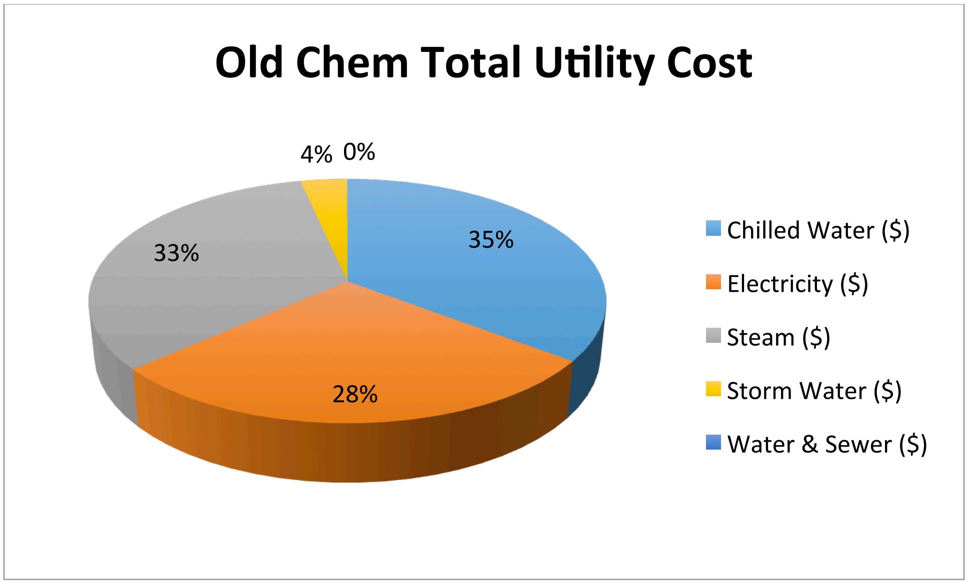


Figure 2.5 Trend of Utility Cost Over Time

According to Figure 2.5, the cost of different utilities has different seasonal patterns similar to their consumption pattern. Steam and chilled water vary according to the season, while electricity, storm water and water sewer remain relatively stable throughout the year.

2.3.2 Total Expenditure



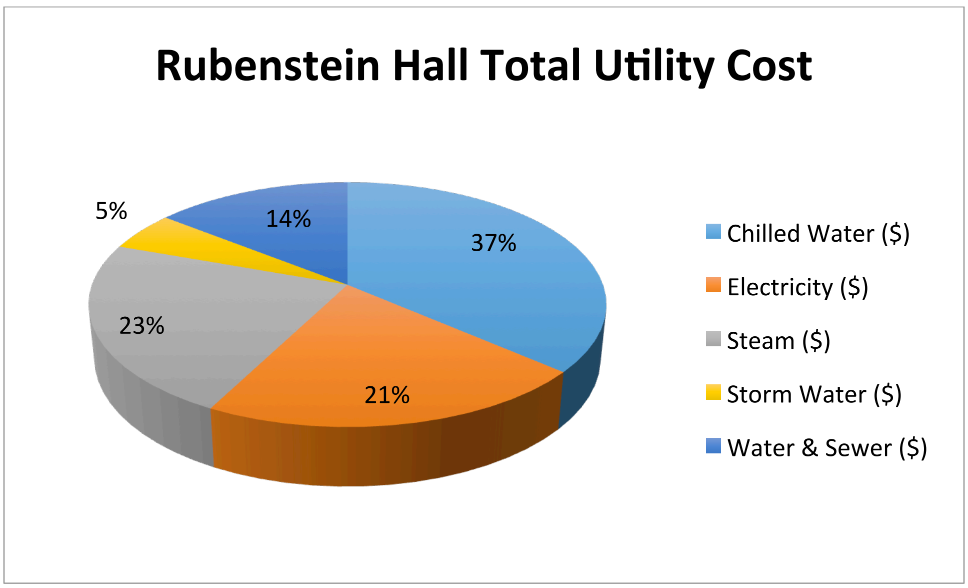


Figure 2.6 Total Utility Cost

If we look at the total utility cost over the five years, for both buildings, expenditure of chilled water is the largest (about 35%), followed by steam (about 30%) and electricity (about 25%). Thus cuts in any or all of these three energy uses represent significant opportunities for savings.

Chapter 3: Analysis of Occupants' Behavior Based on Survey

An occupant survey was used in this project to collect data related to occupants' perceptions, behaviors within their work and study environments. More specifically, we wanted to obtain a comprehensive understanding of whether people on campus were concerned with their energy use, and whether their degree of concern was reflected in the real actions. Furthermore, we wanted to develop an effective, implementable gamification method of promoting energy-conscious occupant behavior, based on their acceptance of gamification identified by the survey results.

To conduct the survey, an online questionnaire created using Quatrics was utilized. To assure that the respondents are familiar with our selected buildings, the survey link was first sent to the school managers whose department is located in Old Chem or Rubenstein Hall, here namely Department of Germanic Languages and Literature, Earth & Ocean Sciences and the Department of Statistical Science, and Sanford School of Public Policy. Then the managers were requested to distribute the online survey to all users, whether master students, PhDs or staff and faculty, of their department using the mailing list. The survey was comprised of an introduction of gamification (even if people have never heard of the term "gamification", they could still gain a basic understanding of this and finish the survey) and consent page, instructions, 12 questions, and a thank you page with researchers' contact information. (Appendix A)

The majority of questions were close ended. In some cases there is an "other" choice to give respondents the chance to type in their personal answers.
Survey questions were divided into the following parts:

- Demographic information
- Awareness and acceptance of gamification
- Energy consciousness

The online survey was officially launched on February 18, after the Human Subjects Protocol Application had been approved.

3.1 Survey Data analysis

By the end of February 25, we collected 93 responses in total. Because of the time limit and workability, we assume the 93 responses could well reflect the overall occupants' perceptions of the two buildings. Among them, 6 responses indicated that they do not occupy either of our two target buildings. Thus we have 87 relevant responses. The effective response rate is 93.5%.

The raw questionnaire results data were first assembled and organized through Excel spreadsheet.

1. In which building is your department located?	Old Chem	29	0	0	29	21	8	29	11	18	29	22	10	15	12	2	27	22	7	29	22
	Rubenstein Hall (Sanford)	0	58	0	58	47	11	58	24	34	58	37	22	28	19	9	54	35	22	57	38
	Other.	0	0	6	6	4	2	6	3	3	6	3	4	2	1	0	5	3	3	6	3
	Total	29	58	6	93	72	21	93	38	55	93	62	36	45	32	11	86	60	32	92	63
2. Do you consider yourself an advocate for the environment?	Yes	21	47	4	72	72	0	72	32	40	72	50	27	36	24	9	67	47	24	71	49
	No	8	11	2	21	0	21	21	6	15	21	12	9	9	8	2	19	13	8	21	14
	Total	29	58	6	93	72	21	93	38	55	93	62	36	45	32	11	86	60	32	92	63
3. Have you heard the term "gamification"?	Yes	11	24	3	38	32	6	38	38	0	38	29	14	18	12	4	34	24	13	37	26
	No	18	34	3	55	40	15	55	0	55	55	33	22	27	20	7	52	36	19	55	37
	Total	29	58	6	93	72	21	93	38	55	93	62	36	45	32	11	86	60	32	92	63
4. What aspect(s) of the gamification (might) attract you? (You can check more than one box, or none of the boxes if you are not interested)	Fun and interesting activities	22	37	3	62	50	12	62	29	33	62	62	26	32	25	5	62	44	17	61	50
	Social interaction with other participants	10	22	4	36	27	9	36	14	22	36	26	36	15	14	5	36	25	10	35	26
	Help you achieve personal goals	15	28	2	45	36	9	45	18	27	45	32	15	45	23	4	45	34	10	44	33
	Attracting rewards	12	19	1	32	24	8	32	12	20	32	25	14	23	32	3	32	24	8	32	24
	Other	2	9	0	11	9	2	11	4	7	11	5	5	4	3	11	11	4	7	11	4

Figure 3.1 Survey Results

3.2 Results

The following section will address the survey results for different questions in the survey.

Part 1

Demographic information

There were 29 survey responses in Old Chem and 58 responses in Rubenstein Hall. 68 out of the 87 respondents claimed that they are environmental advocates. Of all the 29 responses from Old Chem, 21 of them stated that they thought themselves as environmental advocates, which means that about 70% saw themselves as caring deeply about the environment.

Part 2:

Awareness and acceptance of gamification

Of all the 29 responses from Old Chem, 11 of them reported that they have heard of "gamification", accounting for a little less than 40%. For Rubenstein Hall, this rate is also about

40% (24/58). This indicates a relatively low perception rate of gamification. Thus most of the respondents from in both Old Chem and Rubenstein have little awareness of gamification application; still a surprising 40% did.

When asked about which aspects of "gamification" are attractive to them, the responses were dispersed, and is shown in Figure 3.2. "Fun and interesting" ranks NO.1, then follows the "achieve personal goals", "social interaction with other participants", and "attracting rewards". Respondents also have their personal answers, such as "I enjoy competition", "ability to simulate real world", and " see the world from different point of view". Of all the 34 occupants who have heard of the concept "gamification", 29 chose "fun and interesting", while among the 52 people who knew nothing about "gamification", 33 voted for this choice. More than half in both cases. This is noteworthy for our project - when designing a game-based approach to improve building energy performance we need to aim to make it fun and interesting.

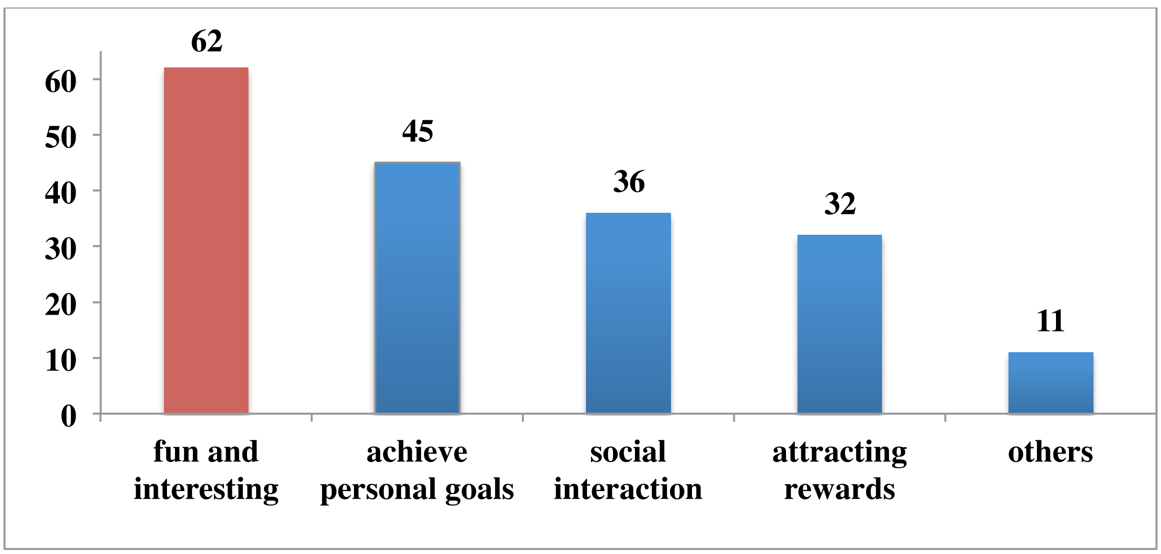


Figure 3.2 Attracting aspects of gamification

63 out of 93 (68%) respondents were willing to participate in a gamified energy-saving related intervention to save energy for their own houses in the future, and the percentage is the same when respondents were asked to save energy for their classrooms or offices. This is an encouraging result.

Of the 71 respondents who checked "yes" of "willing to participate in a gamified energy-saving method", 47 or almost 70% categorize themselves as environmental advocates. Among the remaining 21, 13 (or a little more than 60%) claimed that they would like to take part in a energy saving game. It would appear that a sizable majority of both groups are willing to take part in an energy-saving game.

The length of time that they are willing to contribute to a gamified activity is short, 71 (~80%) students chose "less than 10 minutes". Only 3% of respondents are willing to spend more than 30 minutes. Additionally, within the environmental advocates group, the number of people who chose less than 10 minutes, less than 30 minutes, less than 1 hour and more than 1 hour are 55, 13, 2, and 0 respectively. Within the non-environmental advocates group, the number is 16,4, 0 and 1, respectively. This suggests a major challenge for any gamification strategy with occupants of the two Duke buildings: the games must not only be fun and interesting that also need to be very short in duration.

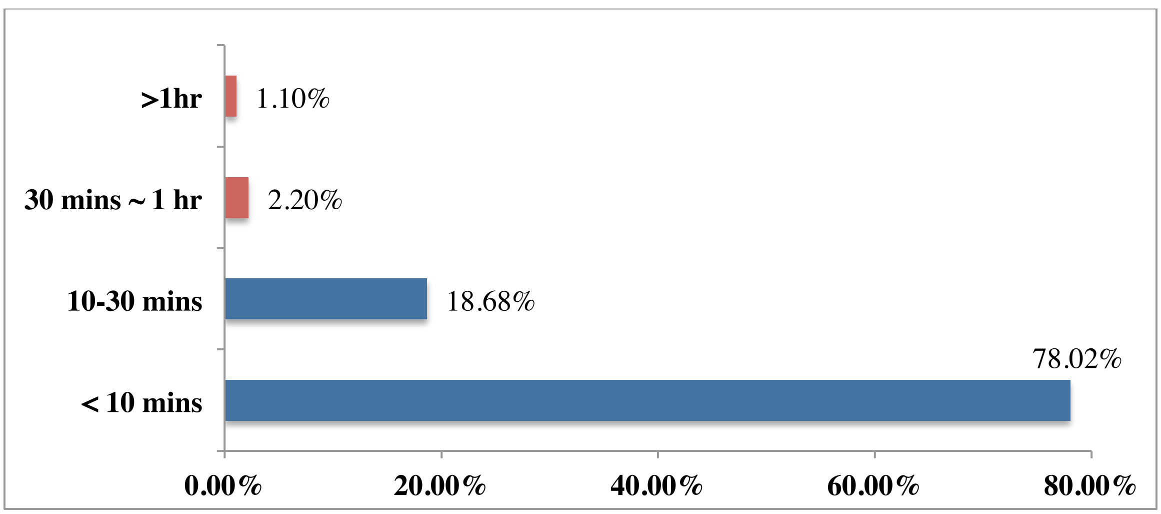


Figure 3.3 Typical time length people willing to spend on gamification

When asked about reasons why they would not like to participate in gamification, 52 (58%) respondents claimed that it is time-consuming, 14 (16%) were concerned with privacy issues, while 11(12%) thought gamification was inefficient to achieve goals. Still another 12 (13%) people reported other opinions, such as "educational games are rather boring", "seems artificial", and even one concerned with the energy required to produce/power the designed game.

It appears that time issue is the major reason why people resist gamified approach.

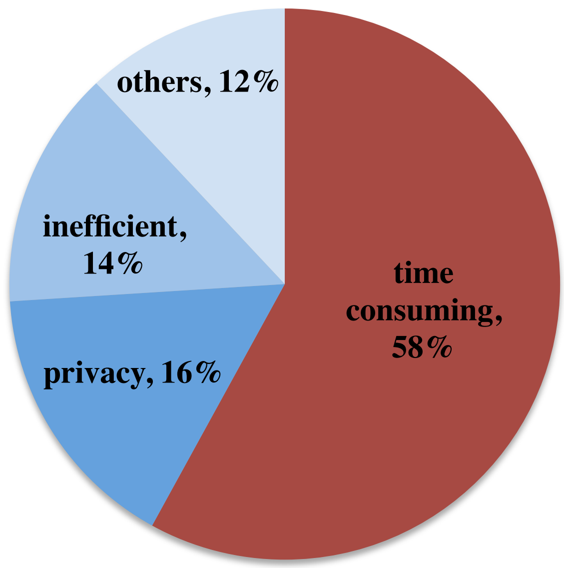


Figure 3.4 Reasons of people reject gamification

Part 3

Energy consciousness

78 out of 93 (84%) respondents thought correctly that heating and cooling is the biggest energy consumer. 53% of all the respondents thought inappropriate setting temperature of heating / cooling wastes the most energy. 23% students thought that over-use of lighting wastes most of the energy in a building. Such responses suggest that the respondents do understand that there is a direct relationship between their behavior and energy usage. What is not clear is to what extent they currently take actions in their daily lives to leverage that relationship.

For the energy information accessibility question, most of the responses indicated, "generally it is accessible", but only 17% are quite satisfied with the transparency of building energy consumption information. In Figure 3.4, on the horizontal axis, 1 represents not accessible at all and 5 represents extremely accessible. This set the point for future development of our gamified approach.

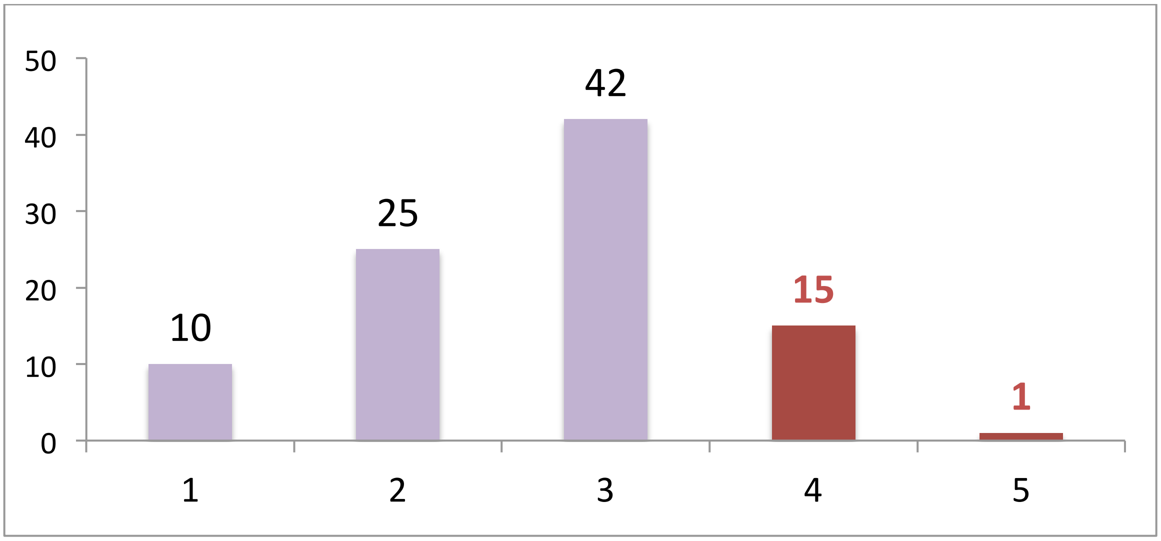


Figure 3.4 Energy data transparency satisfaction

3.3 Conclusion/ Solutions

One of the primary aims of our project is to provide ways of influencing occupants' behavior to decrease energy consumption. Based on survey responses, it appears that efforts towards a greener Duke are to some extent hindered by a general lack of awareness. The results of Question 12 indicate that students are not entirely aware of the energy consumption of their building. Given that awareness is the first step to influencing human behavior, it is imperative to publicize information on environmental initiatives and energy use.

To improve the transparency of energy consumption data, an energy dashboard could be adopted to publicize instant energy use on a per-building basis. If People were more aware of how much they are consuming, they might consider it to be their responsibility and promote conservation. Think about that when you walk into the building like usual, an energy dashboard screen was put in a key location, such as the lobby, which enables you to see the real-time energy use information. Then probably you will feel like that yourself is part of the building, and are motivated to take energy-conscious actions to better conserve the energy.

While raising awareness is an essential step towards fostering a behavior change, it fails to translate into tangible results if members lack personal motivation to get involved.
One way to get people involved in conserving energy through gamification is to harness the potential of friendly competition. For instance, encourage energy saving competitions between buildings with some kind of reward. This will only work if there is energy transparency, information.

The way of how to change people's behavior to decrease use will be further discussed in Chapter 4 in detail. Greater emphasis will be given to promote gamification application on campus.

3.4 Limitation

Because of the time limit and workability, our online questionnaire only got 93 responses, which comprises a rather small fraction of occupants in the two buildings. In addition, as we didn't do an on-site face-to-face survey with a stratified sampling, the respondents might not well represent the occupants of all positions inside the buildings; for example, the percentage of faculty who took part in our survey might not be the same of students. The above survey analysis serves as a general understanding of occupants' energy perceptions and acceptance of gamification of our project.

Chapter 4: Gamification Recommendation

We incorporate findings from survey and data analysis with the Behavioral Change Gamification Model (discussed in Chapter 2) to develop the gamification recommendation. Based on the analysis of building energy data, room temperature control and lighting account for a great portion of the total energy consumption and expenditure in both Old Chemistry building and Rubenstein Hall. Thus, we believe that a gamification strategy focusing on behavior change in setting room temperature and turning off office/classroom lights when leaving could be a desirable and efficient way to reduce energy comsumption in these buildings.

However, Rubenstein Hall currently enrolls in the Temperature Scheduling Program which allows the facility management office to adjust the room temperature to the most energy efficient level for the entire building, whereas Old Chem remains to have occupants adjusting their own thermostat. Therefore, when designing games targeting on room temperature control, we recommend to use Rubenstein as a baseline to evaluate if behavior can yield greater savings when comparing with the Temperature Control Program. More detailed description can be found in Internalization Game.

The recommended gamification event will contain 3 components, Socialization Game, Externalization Game, and Internalization Game. Contrary to conventional games, game or gamified activities in our context refers to activities with game-like elements, including a point system, friendly competitions, and rewards. We anticipate that these activities could lead to the actual behavior change for occupants in campus buildings. Moreover, based on the survey, all games proposed should be within the 10-mintue time constraint in order to be effective.

We recommend that any interested student groups, such as DUGI, could be the facilitators for the gamified events. Students might sometimes communicate and work with building managers to gain permission to perform certain activities in the building and assess the effectiveness of the games. The student group might also consider developing a point system and to award prizes corresponding to the points earned. Participants have the right to use points for redeeming prizes once they meet the requirement. Expense of the prizes should primarily come from funds of student group. Alternatively, student group might consider to work with facility managers to have a share of the saved energy expenses to purchase prizes if possible.

4.1 Recommended Games

4.1.1 Socialization Game

Goal:

The idea of Socialization Game is to use communication for disseminating benefits of participating gamification events and help participants realize the opportunity for improvement. Gathering activities might be most appropriate for Socialization Game because they could serve as an advertisement for the entire gamification event and attract potential participants via social interaction.

Activity:

The student group might send out emails to faculty and students who works and takes classes in Old Chem and Rubenstein, and post signs and use tabling for advertising and having people to sign up (e.g. leaving their email addresses) for the gamification campaign. Moreover, we recommend to conduct a flash mob event during this stage, defined as "a large public gathering at which people perform an unusual or seemingly random act and then disperse…" (Oxford Dictionary). The use of flash mob is, ideally, entertaining to participants and, more importantly, can be performed within the 10-mintue time constraint. The gathering activity could be singing and/or dancing for lowering energy consumption in room temperature control and lighting usage. The student group could use email addresses obtained from tabling to inform potential participants for the event and encourage engagement. Prizes, such as free t-shirt, food, or beverage, will be distributed onsite for every participant.

Anticipated Outcomes:

Flash mob will be performed around the two buildings to inform occupants about the event or even attract them to engage onsite. We anticipate that occupants would be intrigued and will start to search for information through Internet or communicating with participants or acquaintances. Through the power of social interaction, interested individuals could also serve the role to advertise the event to their acquaintances, thus creating a snow-ball effect.

Another outcome the flash mob can accomplish is to raise the awareness of helping improve energy efficiency for campus buildings. Contents for flash mob will convey the idea of benefits, convenience, and importance of saving energy via daily behavior changes. Therefore, it helps participants and observers to realize the opportunity for improvement, which would lead to an increase of participation in the future. Therefore, at the end of the event, activity facilitator can give a brief speech to explain the purpose of the event and ask people to sign up for participating in the future.

4.1.2 Externalization Game

Goal:

Externalization Game will use gamified activities to educate participants the major behaviors that contribute to campus building energy consumption and help them to commit to behavior change in the future. Gathering activities will be recommended again to serve this purpose.

Activity:

Flash mob, due to its advantages in cost-efficiency and short participation time, will again be recommended in Externalization Game. Singings in Externalization Game can be in rap or tongue twister style to increase challenge level which could enhance the entertaining experience. Contents of flash mob should focus on how specific behaviors can affect building energy consumption, how to contribute to energy saving, and should also contain components to help participants making pledge for behavior change, such as shouting or singing “I want to make the change!” It is recommended that singing are taught online prior to the activity for practice and facilitator should print out several copies of the lyrics for those who would like to have them in hand. Rewards will also be distributed onsite for every participant.

Anticipated Outcomes:

During the participation of flash mob, participants would learn the disadvantages of their current behaviors relating to lighting and thermostat usage, and realize the benefits of new behaviors which could make their life as comfortable as current condition but save energy. Flash mob should function as a guideline to prepare participants for taking real behavior change actions.

4.1.3 Internalization Game

Goal:

Internalization Game attempts to motivate participants to take real actions (i.e. adjusting appropriate room temperature and turning off lights). Behavior change will be realized during this stage. Internalization Game often uses point system and leader boards to encourage competitions between participants. Moreover, facilitators could assess the effectiveness of the gamification event during Internalization Game by analyzing the energy data.

Activity:

Activities in Internalization Game will be divided into two separate sections, lighting usage activity and thermostat activity. Each activity will focus on one specific behavior, and each will create both within building and between competitions. Winner will be determined by comparing the energy consumption data. The comparison might focus on percentage rather than in absolute term since the size and function of the building might affect the discrepancy of amount of energy saved.

First, lighting usage activity will primarily focus on saving energy from turning off lights in offices and classrooms. In order to encourage occupants to perform this action, a within building competition is suggested. Occupants will receive points when turning off lights as they leave the room. However, the current utility structure does not provide detailed information on which light remains on while nobody is in the room. Thus, designing a simple web page as an honor system might address the challenge. The system allows participants to self-report on whether they turn off lights by asking a question such as “Did you turn off you lights every time you leaving the office today?” As participants hit the “Yes” button, points will be distributed. Points can be used to redeem prizes, such as coupon or gift card, from the student group. Goal of this honor system is simply to remind participants to practice the new behavior daily. The facticity of the answers, as we believe, is much less important.

The between building competition for lighting usage activity is simple to conduct. Facilitator could compare the building electricity data to determine the winning building that saves more energy. A larger prize, such as a free tour to local recycling plant, will be offered and the distribution schedule will be based on the frequency of the availability of the energy data

Thermostat activity is to encourage participants to adjust the room temperature to the most energy saving mode to avoid "cold room" in the summer or "toasted room" in the winter. As mentioned earlier, since Rubenstein has a Temperature Scheduling Program which disables the thermostat for occupants but allows facility managers to set the energy-efficient temperature for entire building, we would use Rubenstein as a baseline to evaluate if behavior based approach can be more effective for improving building energy efficiency.

Therefore, we recommend occupants within Old Chem to adjust their thermostat based on the room temperature in Rubenstein. For example, if Rubenstein has room temperature 70 ºF, participants will receive points if they adjust their thermostat to 70ºF as well, or more points if lower than 70ºF in the winter and higher than 70ºF in the summer. Participants could use these points to redeem prizes. In order to determine the point distribution, Facility Management Office at Duke has a great monitoring system which allows staff to read information on each individual thermostat in Old Chem. Therefore, points can be distributed based on the reading of thermostat temperature in each room to ensure fairness.

In between building competition in thermostat activity, chilled water and steam will be used to determine the winner. The building with lower energy consumption will win and will receive a larger prize similar to the lighting usage activity.

Anticipated Results:

Internalization Game can help participants taking real actions to improve energy efficiency in campus buildings. It is anticipated that occupants might continue to perform the new behaviors throughout their life if the behavior-based approach is proved to be effective and easy to do. Moreover, if the behavior-based approach effectively saves more energy than the Temperature Scheduling Program, Rubenstein might consider to switch their building management scheme.

4.2 Game Duration, Sequence, and Update

The entire event is recommended to occur over a month. It should start on the first date of each month, and should end on the last of each month. Each monthly event will start with Socialization Game, and its flash mob activity will only be once per month. Flash mob in Externalization Game will begin the day after the Socialization Game and will be performed once a week.

Schedule for Internalization Game should be every day since it targets on daily behaviors. However, the start date of Internalization Game is rather ambiguous, because behavior change could occur anytime as participants learn from previous games. The student facilitator should clearly state the energy saving competition at the beginning of the event, and might need to constantly remind participants. The winners of the between building competition should be publically announced as the energy data is published.

Finally, the amount of points assigned to each activity and at which point level the Combination Game should start need to be determined through collaboration of student group, energy saving experts, and professional game designers. Further, event facilitators might need to evaluate the effectiveness monthly.

4.3 Limitations and Future Suggestions

Since all three authors receive no training in designing games, the gamfication recommendation might experience several challenges when considering real implementation. It is highly recommended to have professional game designers to review the proposal and provide guidance on specific flash mob and competition designs. Moreover, the repeating flash mob activity every week might result in boredom and would result in decrease of participation rate in the future. Thus, a reevaluation of our recommendation might be necessary based on professional judgment.

Furthermore, in Old Chem and Rubenstein, immediate feedbacks are difficult to provide especially with lighting usage, because the entire building has only one electricity meter and the results will be provided only once a month. Therefore, it is impossible to identify who did what and the contribution that particular action performed by that specific person. With these barriers, participants might experience frustration with self-fulfillment when making the behavior changes and the barriers might decrease the participation rate in the future.

Moreover, occupants might bring small electricity appliances to the office, such as space heater. Due to the privacy concern, their appearance and usage are hard to be traced but could have a great impact on electricity usage. Therefore, researches to assess their impacts on energy consumption in the campus building might be necessary in the future.

Finally, some participants might feel being manipulated and might be resistant to engage even with commitment. This challenge is sometimes hard to address and could decrease the effectiveness of the event. Future human psychology research related to the issue might be helpful.

Appendix A: Survey Questionnaire

Consent Form

"Gamification and Going Green"

Changchang Zhou, Yue Feng, and Jing Du

Advisor: William Chameides, Dean of the Nicholas School of the Environment

We are students from the Nicholas School of the Environment doing research on the influence of human behavior on green building and the application of gamification to improve energy consumption. Gamification is defined as "applying game design thinking [such as point scoring, competition with others, rules of play] to non-game applications to make them more fun and engaging…[they] can potentially be applied to any industry and almost anything to create fun and engaging experiences, converting users into players."

The effectiveness of green building design features and technologies is strongly determined by the behavior of occupants, managers, and maintenance staff after occupancy. Our project is focused on ways of altering human behaviors with an emphasis on game-based approaches to enhance building performance. We believe that you can help us by telling your attitudes towards energy consumption reduction in the building sector. We also want to learn what you know about gamification, and the reasons that you might not participate in a game.

If you agree to be in the study, you will be asked to fill out a questionnaire yourself. This questionnaire contains 12 multiple-choice questions and will take about 5 minutes.

Your participation in this research is entirely voluntary. It is your choice whether to participate or not. You may stop participating in the survey at any time that you wish.

If you have any questions, you can ask them now or later. If you wish to ask questions later, you may contact any of the following:

Yue Feng, Master of Environmental Management candidate

Phone: 515-708-1259

Email: yf33@duke.edu

Changchang Zhou, Master of Environmental Management candidate

Phone: 919-813-8036

Email: zcc.900129@gmail.com

Jing Du, Master of Environmental Management candidate

Phone: 919-450-8615

Email: jing.du@duke.edu

If you wish to learn more about your rights as a research subject, you could contact ORS-info@duke.edu, 919- 684-3030.

Gamification Survey

Some organizations and communities use gamified activities to educate people, increase team production efficiency, or change behaviors to support sustainable living. Below are several gamification examples:

1. Cold Stone ice cream company uses Stone City, a computer based simulation game, to educate new employees the importance of correct portioning when making ice cream. In the game, new employees can play the role as an ice cream owner and operate the shop.

2. Carbon Calculator is designed to inform users how much annual CO2 emission produced based on their living habits. The goal is to help users realize the environmental impacts associated with their daily actions and ways to reduce emissions.
3. MyEnergy develops a free web-based program to encourage household energy saving. Households, who agree to participate, publish their energy bills on the web, and compete with other neighbors. Individuals who reduced energy significantly can win credits which can be used to purchase items, such as potato chips, from MyEnergy partners.

If you still have questions, do not hesitate to ask us.

Questions

1. In which building is your department located?

- ☐ Old Chem
- ☐ Rubenstein Hall

2. Do you consider yourself an advocate for the environment?

- ☐ Yes
- ☐ No

3. Have you heard of the term "gamification" before?

- ☐ Yes
- ☐ No

4. What aspect(s) of the gamification (might) attract you? (You can check more than one box, or none of the boxes if you are not interested)

- ☐ Fun and interesting activities
- ☐ Social interaction with other participants
- ☐ Help you achieve personal goals
- ☐ Attracting rewards
- ☐ Other

5. Are you willing to participate in a gamified activity to save energy for your home?

- ☐ Yes
- ☐ No

6. Are you willing to participate in a gamified activity to save energy for your classroom or office?

- ☐ Yes
- ☐ No

7. Are you willing to publish your utility and energy bill to the public?

- ☐ Yes
- ☐ No

8. If you were committed to participate in a gamified activity (even if you do not like the idea…), how many hours would you like to spend on the activity every day?

- ☐ Less than 10 minutes
- ☐ Less than 30 minutes

- ☐ Less than 1 hour
- ☐ More than 1 hour

9. What aspect(s) of the gamification do you not like?

- ☐ Time-consuming
- ☐ Inefficient to achieve goals
- ☐ Being scrutinized (privacy concern)
- ☐ Other

10. Which of the following aspect do you think consumes most energy in your building?

- ☐ Lighting
- ☐ Heating and Cooling
- ☐ Electrical loads
- ☐ Other ________________________

11. Which of the following do you think waste most of energy in your building?

- ☐ Overuse of lighting, such as keeping lights on when no one is there or the natural lighting is enough
- ☐ Unused computers being left on
- ☐ Public electrical equipment such as printers, fax machine being left on all the time
- ☐ Temperature setting point too high in winter and/or too low in summer

12. On a scale of 1(not accessible at all) to 5(extremely accessible), how accessible is information on energy efficiency developments at Duke?

References

1. About LEED. U.S. Green Building Council. http://www.usgbc.org/articles/about-leed
2. Anderson, R. et al (2009). Survey of occupant behaviour and control of indoor environment in danish dwellings. Energy and Buildings, (41), 11-16.
3. Buzz Quiz World: http://www.ign.com/images/games/buzz-quiz-world-ps3-14354806?page=2
4. Clinton J. Andrews, Uta Krogmann. Explaining the adoption of energy-efficient technologies in U.S. commercial buildings, Energy and Buildings (2009) 287–294
5. Csikszentmihalyi, Mihaly. (1997). Finding Flow: The Psychology of Engagement with Everyday Life.
6. Csikszentmihalyi, Mihaly. (Oct, 2009). Flow. Published by Harper Collins
7. Nonaka, Ikujiro; and Takeuchi, Hirotaka. (1995). The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation. Oxford University Press.
8. Davis, Fred D. (1986). A Technology Acceptance Model for Empirically Testing New End-Use Information Systems: Theory and Results. Published by Massachusetts Institute of Technology.
9. Drury B. Crawley, John W.Hand, Michael Kummert, and Brent T. Grinffith. (2005, July). Contrasting the capabilities of building energy performance simulation programs.
10. Enterprise Gamification Consultancy : http://www.enterprise-gamification.com/mediawiki/index.php?title=Target_-_Checkout_Process_at_the_Cashier
11. Fabianoa, G.A. et al. (2008). A meta-analysis of behavioral treatments for attention-deficit/hyperactivity disorder. Clinical Psychology Review, 29(2), 129–140.
12. Flora, S.R. (2004). The power of reinforcement. Albany: State University of New York Press.
13. Fritzsche, D. et al (1981). An analysis of energy consumption patterns by stage of family life cycle. Journal of Marketing Research, 18, 227-232.
14. Green Tech Advocates: http://greentechadvocates.com/2013/04/19/myenergy-looks-to-gamify-efficiency/

15. Green Building, EPA. http://www.epa.gov/greenbuilding/
16. Haas, R. et al (1998). The impact of consumer behavior on residential energy demand for space heating . Energy and Buildings, (27), 195-205.
17. Hoes, P. et al (2009). User behavior in whole building simulation. Energy and Buildings, 41(3), 295-302.
18. Hollywood, Florida, official website. Recycling and RecycleBank: http://www.hollywoodfl.org/index.aspx?NID=423
19. How to Use Gamification for Better Business Results: https://blog.kissmetrics.com/gamification-for-better-results/
20. H. Sachs, S. Nadel, J.T Amann and M. Tuazon, ACEEE. (2004). Emerging technologies/practices: finding the next generation.
21. Korjenic, A. (2011). Impact of lifestyle on the energy demand of a single family house. Building Simulation, (4), 89-95.
22. Kubosumi, A. (2012). Green building renovation: Renewal of hardware, software, human behavior and design process. Epic.
23. Mahdavi, A. et al (2008). Shading and lighting operation in office buildings in austria: A study of user control behavior. Building Simulation, 111-117.
24. Marilyn A. Brown, Frank Southworth. (2006). Mitigating climate change through green buildings and smart growth.
25. Martin, G.; Pear, J. (2007). Behavior modification: What it is and how to do it (Eighth Edition). Upper Saddle River, NJ: Pearson Prentice Hall, ISBN 978-0-13-194227-1
26. Miltenberger, R. G. Behavioral Modification: Principles and Procedures. Thomson/Wadsworth, 2008.
27. Myers, S.M. et al (2007). "Management of children with autism spectrum disorders". Pediatrics 120 (5): 1162–82. doi:10.1542/peds.2007-2362. PMID 17967921. Lay summary – AAP (2007-10-29).
28. Ouyang, J. et al (2009). Effects of improved consumer behavior on energy conservation in the urban residential sector of hangzhou, china. Journal of Asian Architecture and Building Engineering, 8(249), 243-249.
29. Oxford Dictionaries. Flash mob. http://www.oxforddictionaries.com/definition/english/flash-mob#m_en_gb0972977

30. Peng, C. et al (2012). Quantitative description and simulation of human behavior in residential buildings. Building Simulation, (5), 85-94.
31. P. Jacobs, H. Henderso. (2002, Feb). State-of-the-art review whole building, building envelope, and HVAC component and system simulation and design tools.
32. Raaij, W. (1983). Patterns of residential energy behavior. Journal of Economic Psychology, (4), 85-106.
33. Reckien, Diana and Eisenack, Klaus. (March 13, 2013). Climate Change Gaming on Board and Screen: A Review. Simulation Gaming 2013, (44), 253
34. Retrieved from: http://www.architect.duke.edu
35. Retrieved from: http://www.fmd.duke.edu
36. Retrieved from: http://www.eia.gov
37. Santin, O. (2011). Behavioural patterns and user profiles related to energy consumption for heating. Energy and Buildings, (43), 2662-2672.
38. Seligman, C. (1977). Behavioral approaches to residential energy conservation. Energy and Buildings, 325-337.
39. Stanton W. Hadley. (2004). Emerging energy-efficient technologies in buildings: technology characterizations for energy modeling.
40. Thorndike, E.L. (1911), Provisional Laws of Acquired Behavior or Learning. Animal Intelligence.
41. U.S Department of Energy, Building Energy Software. http://www.doe2.com/
42. Velicer, Wayne F.; Prochaska, James O.; Fava, Joseph L.; Norman, Gergory J; and Redding, Collen A. (June, 1998) Smoking cessation and stress management: Applications of the Transtheoretical Model of behavior change. Homeostasis in Health and Disease.
43. Weber, C. (2000). Modeling lifestyle effects on energy demand and related emissions. Energy Policy, (28), 549-566.
44. William E. Roper. (2007). State-of-the-art review for sustainable building design and innovation technologies.
45. Wolpe (1958). Psychotherapy by Reciprocal Inhibition.
46. Ying Li. (2012) . Study on sustainable buildings. Applied Mechanics and Materials Vols. 174-177 pp 3146-3149